Report for 2004PA27B: Split-Flow Stormwater Demonstration and Feasibility Study

- Conference Proceedings:
  - Echols, S. 2004. Split-Flow LID Stormwater Strategy: How to Improve LID Design to Eliminate the Need for Detention Systems. Proceedings of the Putting the LID on Stormwater Management Conference, B.M. Rustia (ed.) Washington, DC: Metropolitan Washington Council of Governments. pp. 380-385.
  - Echols, S. 2004. Split-Flow Stormwater Strategy BMPs. Abstract in Proceedings, Southeast Regional Conference on Stormwater, Emerging Issues for Local Communities. April 19-22, 2004, Ashville, NC.
  - Echols, S. 2003. Introduction of a New Distributed Split-Flow Stormwater Design Strategy. Proceedings of the 2003 American Society of Landscape Architects Annual Meeting. J.M. Brown (ed.). Washington, DC: American Society of Landscape Architects. pp. 81-85, ISSN 10907432.
  - Echols, S. 2003. Implementing Stormwater Management through Split-Flow Drainage Design. Proceedings of the 2003 Pennsylvania Stormwater Management Symposium. R.G. Travel, Conference Chair, C. Emerson (ed.). Villanova University: Philadelphia, PA.
  - Echols, S. 2003 A New Split-Flow Sustainable Urban Drainage Strategy. Proceedings of the Second National Conference on Sustainable Drainage. C.J. Pratt, J.W. Davies, A.P. Newman and J.L. Perry (eds.). Coventry University: Coventry, UK. pp. 113-119, ISBN: 1903818273.
  - Echols, S. 2003. Developing Split-Flow Stormwater Systems. Proceedings of the US EPA National Conference on Urban Stormwater: Enhancing Programs at the Local Level. R.J. Kirschner (ed.). Cincinnaati, OH: U.S. Environmental Protection. pp. 114-121, EPA/625/R-03/003.

Report Follows

Abstract:

Engineers, Planners, Water Resource Professionals, Local Government Officials and Land Development Professionals are expected to plan and regulate urban developments that protect and restore our natural ecosystems. However, every time we create a new impervious building, plaza, sidewalk or parking space, we increase runoff and degrade our aquatic environments. As a result of new federal regulations, thousands of municipal governments are now required to develop, adopt and implement stormwater management strategies to reduce non-point source pollution directly related to new development. Despite these regulations, current stormwater management strategies have shown only limited success in protecting aquatic environments that depend on the preservation of existing natural processes. To address this issue, we need a new stormwater management strategy that regards runoff as a valuable resource, emulates the natural hydrology system, fulfills our environmental goals, and satisfies local flood control regulations. The Split-Flow Stormwater Management Strategy is a newly developed method for managing stormwater on-site by replicating the natural processes of evapo-transpiration, soil infiltration and stream flow. This Split Flow strategy has been modeled and studied by comparing its design feasibility and construction cost to other methods with promising results. However, development of the strategy is at a standstill due to a lack of in-ground testing. The purpose of this proposal is to implement initial in-ground testing of the strategy. The knowledge gained from the proposed in-ground testing will offer practical evidence of the strategy's usefulness and reveal areas in need of further refinement.

The study will be the first in-ground test to assess the Split-Flow Stormwater Design Strategy's ability to replicate natural discharge flow rates, volumes, frequency and duration by comparing runoff discharges from parking lots equipped with Split-Flow systems to runoff discharges from undeveloped adjacent analogous land. The primary objective of this study is to test the Split-Flow Stormwater Management Strategy's efficacy in preserving the land's natural stormwater discharge rates, volume, frequency and duration. Another outcome of the study will be the creation of a sustainable stormwater management demonstration and education facility within the Spring Creek Watershed, located in Centre Country, PA. The longer-range goal of this study is to continue development of the Split-Flow Stormwater Management Strategy in order to provide an ecologically responsible stormwater management alternative based on preserving the land's pre-development hydrological processes. Funding provided by the PA Water Resources Research Center will be used to procure monitoring equipment for the Split-Flow demonstration including: stormwater flow, rainfall, soil moisture, water & air temperature, water depth meters and on-site data recording equipment.

The Split-Flow needs to be tested before it can be applied to land development practice where it should help resolve many of the problems that current stormwater management methods need to address. As a result of Split-Flow strategy, the actual difference in volume created by development can be distributed throughout a site to restore groundwater recharge; natural runoff that existed before development can be cleaned and routed downstream; and the first flush containing the highest levels of pollution can be diverted and isolated in effective treatment facilities. Under such conditions, the reduction in downstream degradation should be quite substantial.

Statement of Critical Need:

The national significance of this project is widespread because all municipal regions with a population greater than 100,000 are legally required to address non-point source pollution problems created by excess urban runoff. At the international level, urban runoff problems have been and continue gaining increased attention with innovative solutions being sought. In-ground testing of the Split-Flow Strategy will establish the strategy's utility, reveal areas in need of further refinement, and will advance our understanding of how stormwater design can more effectively incorporate environmental stewardship into land development. By establishing the Split-Flow Strategy's utility, land developers and communities who are hesitant to use new stormwater designs will have tangible evidence of this strategy's application and usefulness.

Statement of Results of Benefits:

The outcome of this study will be five-fold. First, the study will assess the Split-Flow Stormwater Design Strategy's ability to preserve natural stormwater discharge flows, providing a better understanding of the strategy's potential application for protecting aquatic environments and enhancing its practical application in land development practice. Second, the test sites will serve as public demonstration facilities for both Penn State students and watershed conservation groups. Third, graduate students from the Center for Watershed Stewardship, the Department of Landscape Architecture, and other related disciplines will have opportunities to participate in the refinement and revision of the Split-Flow Stormwater Design Strategy by collecting and analyzing data from the test facilities, as well as participating in the Split-Flow facilities' design, construction, and maintenance. Fourth, interpretative signage will explain the facilities' functions and the importance of ecological stormwater design for the protection of aquatic systems in the Spring Creek Watershed. Lastly, locating the facilities within existing campus parking lots will create additional educational opportunities for local residents and visitors to Penn State's University Park campus.

Nature, Scope and Objectives:

Nature and scope - The basic premise of Split-Flow stormwater management strategy is that rainfall can be divided into three portions specific to any given design storm, that these portions should reflect predevelopment evapotranspiration, infiltration and natural runoff volumes based on existing conditions, and that these portions can then be filtered, distributed and redirected respectively into bioretention, recharge and downstream discharge. The Split-Flow strategy preserves a site's predevelopment hydrology by a combination of distributed bio-retention facilities that overflow into raised drop inlets and paired Vee-notch flow splitters connected to small infiltration facilities. Runoff is directed to bioretention facilities where the designated first flush volume of contaminated urban drainage is retained by mulch, soil and plant material. These bioretention facilities are designed as separate off-line facilities to assure that first flush pollutants are not re-suspended and released downstream. The facilities are sized based on the predevelopment initial abstraction runoff depth for each

impervious surface. This simple ratio of parking to bioretention area can be easily applied to small parking lots and still allow area for tree planting in the medians as shown in figure 1.

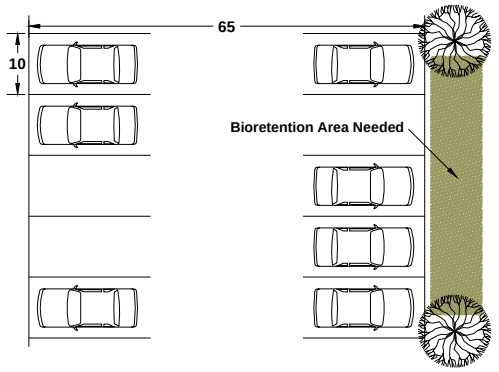

Fig. 1 - Bioretention area needed for small parking lot

By sizing the facility for 1.3 inches, any storm with less than 1.3 inches of rainfall would be held completely on site. Storms with more then 1.3 inches of rainfall would overflow into a raised drop inlet with a proportional flow-splitter. The basic design concept of a bioretention area with a raised drop inlet and flow-splitter is shown in figure 2.

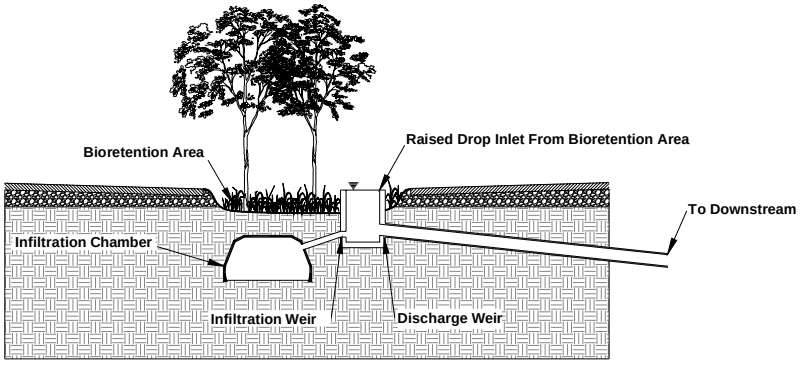

Fig. 2 – Basic Design Concept for Bioretention Facility with Flow-Splitter

After entering the raised drop inlet, runoff is separated by a proportional flow splitter into the infiltration and discharge hydrographs. The proportional flow splitter consists of paired weirs designed to split the runoff so that the portion of the post development hydrograph created by buildings and impervious surfaces is diverted into infiltration facilities and the natural runoff that existed before development is discharged downstream. The total difference in volume between any pre and post development design storms is calculated with the equation: (post Qp - pre Qp) x ToC x 80.1. This method closely recreates the pre-development hydrograph by infiltrating the additional runoff volume created by development as shown in figure 3.

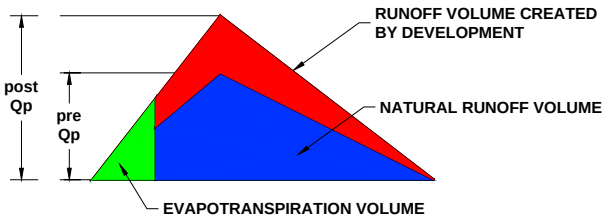

Fig. 3 - Development Volume Hydrograph

The discharge weir is designed to capture the pre-development runoff volume while the infiltration weir is designed to capture the increase runoff volume caused by development based on pre and post development conditions. These two weirs combine to act as a proportional flow splitter as shown in figure 4.

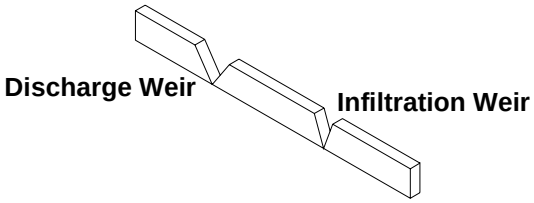

Fig. 4 – Proportional Flow Splitter

Each weir angle can be sized with identical heads and different flow rates based on the pre-development flow rate and the difference between the pre and post-development flow rate. For example, if the pre-development peak runoff rate is 5.6cfs and the post-development peak runoff rate is 8.5cfs, the bypass weir angle can be sized for 5.6cfs and the diversion weir angle can be sized for 2.9cfs. Using a Vee-notch weir nomograph, the bypass weir angle would be 120 degrees and the diversion weir angle would be 90 degrees. These weirs can be easily built into plastic drop inlets as shown in figure 5.

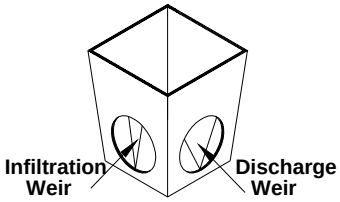

Fig. 5 - Plastic Inlet With Weirs

The importance of dividing the site into small drainage areas and distributing the system over the entire site in numerous small facilities cannot be over emphasized. An important aspect of this method is that the design for the paired Vee-notch weirs is based on proportions and not the overall capacity. Runoff is split into these proportions regardless of the Vee-notch height, storm intensity or duration. In other words, the system is not designed for a specific design storm but rather it is designed to split the flow into a specific ratio for all storms large and small. This fact provides an immense advantage over existing methods. The key for success with this management strategy is to install proportional flow splitters for each impervious surface and distribute the flow into individual facilities. This is achieved by

sizing the angles on each individual pair of Vee-notch weirs to discharge the predevelopment runoff volume and to infiltrate the increased runoff volume created by impervious surfaces. By customizing each proportional flow splitter's weir angles to match predevelopment hydrologic conditions, the Split Flow system adapts itself to the unique conditions of and within any site. The site specific design of each proportional flow splitter assures that peak flow rates are effectively controlled without the need to exceeds a site's predevelopment infiltration capacity. The system controls the overall peak flow rates by distributing and infiltrating the difference in volume proportional to time over the entire site and therefore eliminates the need for any stormwater detention system.

Objectives of the project - The primary objective of this study is to test the Split-Flow Stormwater Design Strategy's ability to preserve the land's natural stormwater discharge rates, volume, frequency and duration. The funding requested will assist in creating a sustainable in-ground stormwater design demonstration and education facility on Penn State's University Park campus. These test sites will serve as demonstration facilities for Penn State students and watershed conservation groups. The site will also become a public educational facility with on-site interpretive signage that explains not only the facility's function, but also the vital role ecological stormwater management plays in the protection of aquatic systems throughout the Spring Creek Watershed. Graduate students from the Center for Watershed Stewardship will participate in the Split-Flow facility design, construction, maintenance, collect and analyze data from the test facilities. By locating the facilities within existing campus parking lots, additional education opportunities will be created for local residents and visitors to Penn State's University Park Campus.

Timeline of activities

Fall 2003 – preliminary test sites identified by Penn State
Winter 2004 – conduct soil and percolation test on test sites
Spring 2004 – construct Split-Flow demonstration facility
Summer 2004 – install water flow and depth meters
Fall 2004 – collect preliminary stormwater flow data
Winter 2005 – recalibrate proportional flow splitters
Spring 2005 – collect adjusted stormwater flow data
Summer 2005 – analyze adjusted data and compare results

During the first year, preliminary reports about the research design and information gained during construction will be submitted for peer review and presentation at regional and national stormwater conferences. The project is expected to continue for two years after the funding period. During the second year, reports detailing the Split-Flow Stormwater Design Strategy's ability to replicate natural discharge rates, volumes, frequencies and durations will be submitted for review and publication to peer-reviewed journals, including: *Urban Water,* the *Journal of American Water Resources Association*, the *Journal of Water Resources Planning and Management* and *The International Journal of Water*. During the third year, project results will be presented at conferences, and submitted for peer-reviewed publication at both national and international levels. Educational brochures and web-based information will be made available throughout the research process as funding permits. The final

deliverable from this project will include an ongoing Split-Flow stormwater design demonstration/education facility on the Penn State University Park campus.

Principal Findings and Significance:

We are currently in the process of building the pilot Split-Flow feasibility test facility. We have spent most of the past two years working with Penn State to design a feasibility and demonstration study as part of the new School and Architecture and Landscape Architecture building. Unfortunately, after investing considerable time and effort by our department and outside consultants, Penn State OPP decided that they would not approve the feasibility and demonstration study at the new building site. We are, therefore, temporarily using an off campus site to build a pilot feasibility test facility until we can find a highly visible campus location that is suitable for the long-term feasibility and demonstration study and receive construction approval from OPP. This change actually works out fairly well because it gives us a better opportunity to work out all the details and make design revisions as needed before we construct the on campus feasibility facility.

The PA Water Resources Research Center grant funds have been used only to purchase equipment that can be easily and safely relocated to the future on campus feasibility and demonstration facility. I am personally funding the construction materials and labor for the pilot study thereby assuring that funding provided by the PA Water Resources Research Center will only be for equipment that can be reused for the long-term feasibility and demonstration facility. We are currently fabricating control weirs and calibrating flow interments. We hope to have the pilot Split-Flow feasibility test facility completed in the next few weeks and start gathering data over the summer.

Students Supported:

None at this time.

Presentations and Other Information Transfer Activities:

Echols, S. 2004, "New Technologies for Stormwater Restoration," Invited presentation at the University of Georgia, School of Environmental Design, April 19, 2004 Athens, GA.

Echols, S. 2005 , "Split Flow Drainage Systems," Invited presentation at the New Jersey American Society of Landscape Architects Annual Conference, February 7, 2005.

Awards:

None at this time